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TROPICAL WATER SUPPLIES, WITH SPECIAL REFERENCE TO THE CANAL ZONE AND TO VERA CRUZ, MEXICO[1]

By James T. B. Bowles[2]

In writing this paper it was not the writer's idea to go into details concerning these water supplies, but to give their development in outline.

Many years ago, when the Nicaraguan Canal was proposed, Surgeon-General Sternberg discussed the municipal water supplies of Nicaragua, and placed much stress upon its great importance.

Later, before the American régime, when General Gorgas made his first sanitary survey of the Canal Zone, Major Gillette, then captain in the engineering corps of the army, accompanied him and reported upon the possible sources for water supplies.

It was recommended that at least part of the water supplies should be obtained from driven wells. But it was soon discovered that sufficient water could not be thus obtained and it was necessary to look elsewhere for water.

During the early days of the American occupation, the installation of an adequate and uncontaminated water supply was the all important point. At such a time, with a great scarcity of material and at a great distance from supply depots in the United States, and often when a piece of pipe was ordered, a wheelbarrow or shovel was sent, no time or thought could be given to the design of elaborate and fancy water supply systems. The all important point was to obtain some kind of a pipeborne water supply. Little did it matter then whether or not the joint was perfectly smooth, or whether the pipes were of the same kind, and in some cases they were of different sizes, all were jointed together in some way. It was this water supply which saved the day, as it was not until a pipeborne water supply was installed that yellow fever was entirely eradicated. In fact, the writer thinks that General Gorgas considers the installation of the pipeborne water supply the most important means in doing away with yellow fever.

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[1] Read at meeting of Four States Section, Philadelphia, January 18, 1916.

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It is most interesting to see how this original water supply has been developed into what now might be called the most efficient and the most modern system of water purification in Central or South America.

Speaking in general, the water supply for the cities of Panama and Colon, and the small villages along the line of the Panama Railroad, consisted of small impounded streams forming reservoirs. In some cases the Chagres River or tributaries of it were used, and wherever this was done the towns and villages were furnished with condensed water for drinking purposes.

Starting from the Atlantic side, and going toward the Pacific, there was in the beginning the old Panama Railroad reservoir back of Monkey Hill. Its water was used to supply the Panama Railroad and a few buildings in Colon. Water was sold from barrels and stations. In 1906 the Brazos Brook Reservoir with a capacity of 640,000,000 gallons was completed. It supplied the cities of Colon and Cristobal. The water from this reservoir was practically surface and rain water caught during the rainy season, and held for use during the dry season. At certain times of the year, the water had quite a distinct odor and color, but was practically free from any contamination, as the watershed was entirely policed. A few years later pressure filters were installed, and after that a sedimentation basin, and the water was treated with aluminum sulphate.

Gatun originally obtained its water from the Chagres River, and condensed water was distributed among the houses. Later in 1910, Agua Clara Reservoir with a capacity of 600,000,000 gallons was constructed. Two years later a mechanical gravity filter plant was constructed with a capacity of 2,500,000 gallons per day, when running at the rate of 125,000,000 gallons per acre per day.

Carabali Reservoir, constructed in 1906, with a capacity of 160-000,000 gallons, supplied the town of Gorgona. There was always more or less trouble from algae growths in all the reservoirs, but Carabali gave the most trouble. However, it responded very readily to the copper sulphate treatment.

Camacho Reservoir, constructed in 1907, with a capacity of

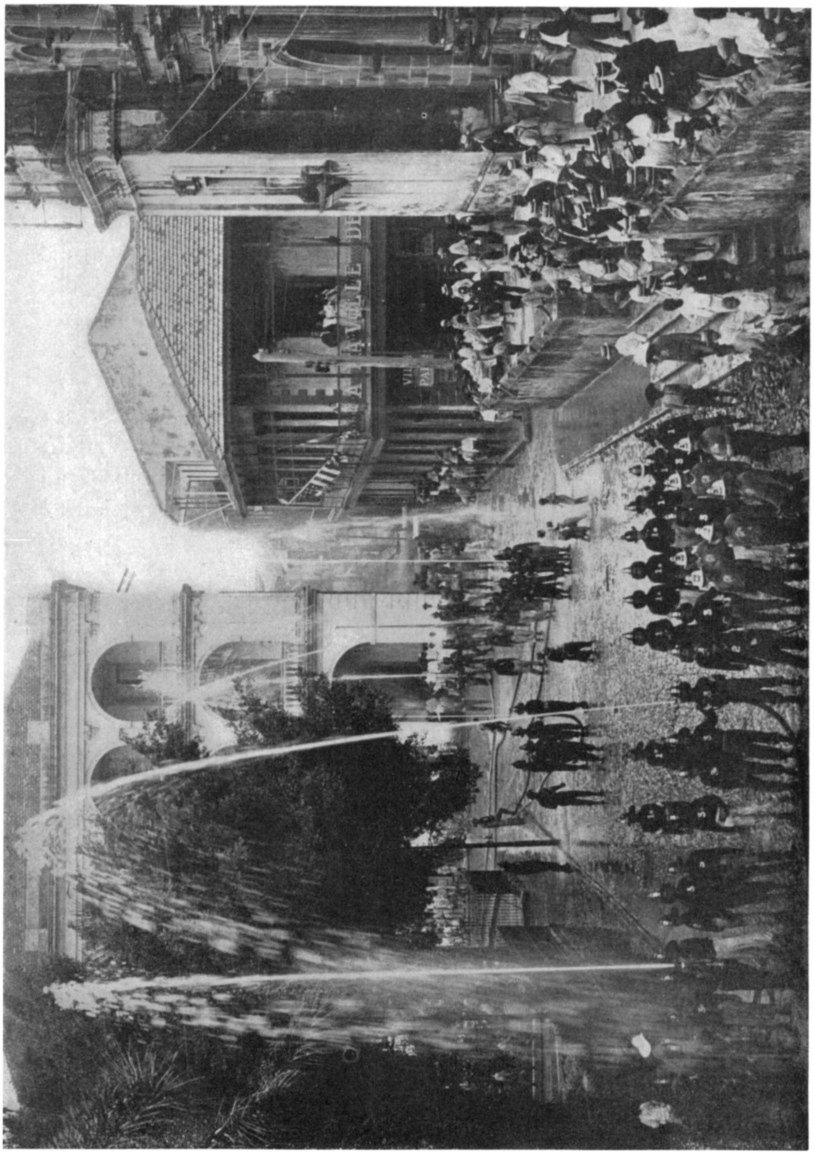

FIG. 1. INSTALLATION OF PIPE-BORNE WATER SUPPLY BY THE AMERICANS IN PANAMA CITY

375,000,000 gallons, supplied the town of Empire. This reservoir gave the least trouble of any in regard to tastes and odors.

Rio Grande, constructed in 1906, with a capacity of 487,000,000 gallons, supplied the towns of Culebra and Ancon. This water was low in bacteria, but at times had bad odors and tastes. At Ancon the water was filtered by pressure filters without use of a sedimentation basin.

Cocoli Lake was a temporary auxiliary supply for Culebra and Ancon.

The above is a description of the water supply as it existed during most of the construction period. It was constructed with no particular idea to permanence, but with an idea of taking care of the immediate use. It answered the purpose well, and served to prevent many waterborne diseases.

The building of the modern filtration plant at Gatun was the beginning of the permanent water supply system for the Panama Canal.

There was always a great lack of water for Colon and Cristobal. This led to the building at Mt. Hope of a new mechanical rapid gravity filtration plant having a capacity of 7,500,000 gallons per day designed by Mr. George M. Wells, Resident Engineer.

Brazos Brook Reservoir was still to be used, but its capacity was increased by digging a tunnel into Gatun Lake. At a certain portion of the upper end of Brazos Brook, only 500 feet from the upper end of Gatun Lake, the two lakes were connected at elevation +75. A gate house at the tunnel controls the flow by a float valve, keeping Brazos Brook always at the same level. The water flows by gravity from the reservoir to Mt. Hope filtration plant, where it enters an aeration chamber through bronze nozzles arranged to give a fine spray. It next passes through a mixing chamber where it receives an automatically controlled dose of aluminum sulphate. After being thoroughly mixed it flows through the sedimentation basins to the filters, and is pumped from the clear water well, which is beneath the filters, to the city. Electrically driven pumps are now being used at all stations.

The typhoid fever rate has always been exceptionally low, practically nil. At two different times there were a few cases. Once the cause was a carrier, and once the cause was oysters from Panama Bay. There was no spread of the disease. The dysentery rate was always low, exceptionally low for a tropical country.

In 1912, General Goethals appointed a committee, consisting of Admiral Rousseau, Mr. G. M. Wells, Mr. Cole and the writer, to make a study, and to locate sites and to submit plans for a permanent water supply for the towns south of Pedro Miguel, including the cities of Panama, Ancon and Balboa. A thorough study was made of all possible sources after an estimate had been made of the probable amount of water that would be needed per day for all of these towns, taking into consideration the adjustment of the cities and their growth after the Canal was completed. It was finally decided to use the small lake at Miraflores, east of the Panama Railroad. This lake was fed by the two rivers, Caimatilla and Caimeron. It was connected with the main Miraflores Lake by a culvert under the railroad. In times of dry weather there would not be enough flow from the rivers to prevent the Miraflores Lake from backing up into the small lake. The committee did not like this, feeling sure that Miraflores Lake would increase in salt content on account of the lockages, and thinking that it would give trouble by raising the chlorine content of the water supply. In the report to the chairman

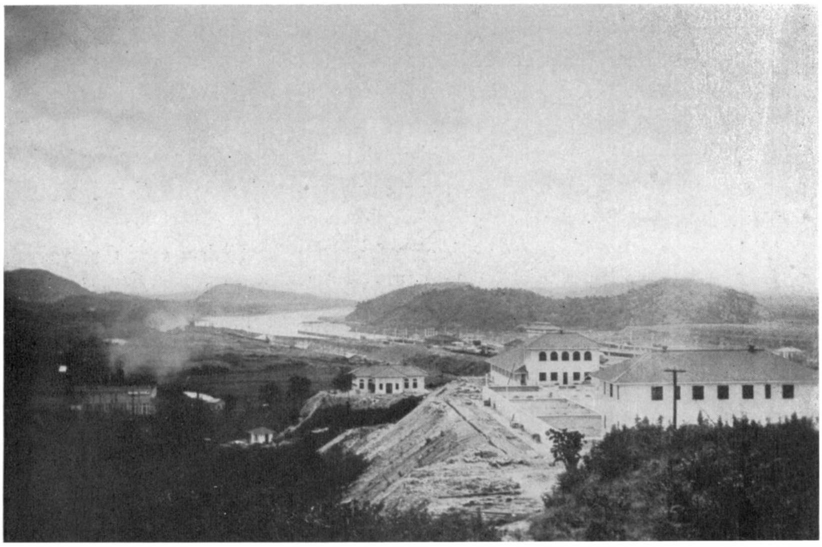

FIG. 2. THE NEW MIRAFLORES FILTRATION PLANT WHICH FILTERS THE WATER FOR PANAMA CITY, AND OTHER CITIES ON THE SOUTHERN SIDE OF THE ISTHMUS

and chief engineer, the question of contamination from salt water was brought to his attention. As an alternative it was suggested, if the Miraflores water could not be used, that the water be obtained from the Chagres River at Gamboa, at some point up the river where there would always be a current.

The chief engineer felt that that point had been considered previously by the canal engineers, that they had decided that there would be no special increase in the chlorine content, and therefore he felt that the water supply would not be affected by salt water. Work was started at Miraflores, and Mr. G. M. Wells was appointed to design the entire plant.

The plan was to have a pumping station at the lake east of the Panama Railroad. The water was to be pumped to a mechanical gravity filter plant on Miraflores hill, a short distance away. The capacity of this plant is 15,000,000 gallons per twenty-four hours, running at the rate of 125,000,000 gallons per acre per day. The water is pumped to an aeration basin which contains nozzles arranged to give a very fine spray in order to aerate the water as much as possible. From the aeration basin the water passes through the head house, where it receives a dose of aluminum sulphate, and after being thoroughly mixed by passing over and under a series of baffles, the water flows into the sedimentation basin, which is very long and well baffled so that the water has sufficient resting period before it flows onto the filters.

At the Miraflores filtration plant there is uniformity in the distribution of wash water and rate of filtration, low maintenance cost and a minimum of strainer trouble and loss of sand. This had been brought about by incorporating as the main feature of the design of the underdrainage system a false bottom or pressure chamber in place of the usual ridge block and pipe systems. Water under a pressure of 28 pounds per square inch is carried into the filters through feed pipes with their upper ends deflected 180 degrees so that the flow of wash water is deflected downward upon the filter floor or gravel bed. These feed pipes have been fitted with strainers, but test results have shown that in this type of underdrainage system strainers are unnecessary.

CHARACTER OF THE WATER

Under ordinary conditions the turbidity of the raw water is low, but after heavy rains on the watershed of the river it is increased to a few hundred parts per million.

AERATION

On account of decided odors intermittently present the raw water is first discharged into an aeration basin through 105 nozzles, which are arranged in seven batteries of 15 each. During the months of April, May and June, 1915, the dissolved oxygen in the raw water was increased from an average of 55.8 to 88.7 per cent of saturation. During the same period the free carbonic acid was reduced from an average of 2.6 to 0.5 parts per million.

The aerated water flows over three weirs into the three concrete mixing chambers located in the basin of the head house. The alum solution is added to the aerated water as it enters the first compartment of the mixing chamber. During the months of April, May and June, 1915, the alum averaged 192 pounds per million gallons, varying from a minimum of 101 to a maximum of 471 pounds per million gallons.

From the mixing chamber the water passes into three crossconnected parallel concrete sedimentation basins; the length of each basin is 300 feet. The combined width of the three basins is 125 feet. The depth of the floor valleys is 17.75 feet. At the present time an average sedimentation period of twelve hours is obtained.

Each basin is divided into three compartments by two pressure baffle walls. Extending across these baffle walls in front of the openings there are concrete skimming troughs which reach to within about a foot of the normal water level. Between the pressure walls there are two light baffle walls which contain four openings, 6 feet wide extending from within 2½ feet of the top to 3 feet from the bottom of the basin. In addition to the baffling effect they prevent wave action which would otherwise result, from the strong wind which prevails at certain times. All valves are hydraulicly operated, controlled from an operating table located in the head house.

CONSTRUCTION OF FILTERS

The fourteen rapid sand gravity filters are constructed of reinforced concrete, and measure 19.75 by 21.5 feet, and 11 feet deep to the floor, in which the underdrainage system is placed. Each unit has a sand area of 425 square feet.

Thirty inches of Chame sand, with an average effective size and uniformity coefficient of 0.4 and 1.9 respectively, and 2 inches of Chagres River gravel, arranged in three layers, comprise the filtering medium. An independent air system, to be used only in case hard spots and mud patches develop, is placed between the small and medium grades of gravel.

When a filter is washed at a rate of 15 gallons per square foot of sand surface, equivalent to a 24-inch rise of wash water per minute, a pressure of about 16 pounds per square inch is developed on the false bottom, and the sand bed is raised 8¼ inches above its normal elevation.

It is true that false bottoms have been used in filters built prior to these, but they have been designed for low pressures and rates of flow of wash water. As far as the writer knows these filters are the only ones embodying concrete false bottoms which will withstand a maximum pressure of 28 pounds per square inch and will allow a vertical rise of wash water of 2 feet per minute with an ample margin of safety.

Starting March 15, during the first ten days of operation, the percentage of wash water averaged 8.8, but dropped to 2.35 the remaining seven days of the month.

During the early part of the construction work of the plant the writer carried on a very elaborate survey of the chlorine content of the water. Regular stations were made from the sea side of Miraflores Locks, through the locks, into Miraflores Lake, through the channel and on either side of the channel, through Pedro Miguel Locks, a short distance into Culebra Cut, then from Miraflores Lake, through the culvert under the Panama Railroad, to six or eight stations distributed over the small lake on the east side of Panama Railroad, and to one station at the proposed intake in this lake.

At first, lockages were made from both ways into Miraflores Lake, then Miraflores Lake was lowered 10 feet, then raised to normal elevation, samples being taken before and after these movements. Then samples were taken twice a week at the regular stations as named above for several months. The result showed a gradual increase in the chlorine content. Owing to the fact that Rio Grande Reservoir could not supply enough water it was necessary to establish a temporary pumping station in the proposed lake at once. This water was treated with hypochlorite before it entered the mains, and was afterwards filtered in Ancon through the old pressure filters. When the chlorine content of the water reached 65 or 70 parts per million, much trouble was had with the boilers at the Miraflores Power Plant.

After these results from the high chlorine content were obtained, the Chief Engineer decided to use the Chagres River water. Of course this change made unnecessary the proposed new pumping station at the lake east of the Panama Railroad at Miraflores. Fortunately, the construction of this station had only been just started, so there was no great loss. Going to the Chagres River meant the laying of a pipe line 9 miles long. There was no change in the location of the filter plant, as the point chosen was the logical situation for it. It was necessary temporarily to extend a pipe line into the "Cut" just beyond Pedro Miguel locks in order to obtain water to dilute the old supply which was high in chlorine.

After filtration, the water passes through a Venturi meter, where it receives a dose of hypochlorite of lime. Liquid chlorine is being installed. Excellent water, and plenty of it, is now being furnished by the finest filtration plant in South or Central America. Its location is very unique, as it overlooks on one side, Culebra Cut, Pedro Miguel and Miraflores Locks, and on the other side, Panama and Balboa Bay.

With the new filtration plants at Mt. Hope and at Gatun, and the newly completed plant at Miraflores, the water supply question of the Canal Zone and the cities of Panama and Colon ought to be settled for many years to come.

WATER SUPPLY OF VERA CRUZ, MEXICO

There are two water supply systems for Vera Cruz. The main supply coming from the Jamapa River and filtered at Tejar is used everywhere. The other supply coming from the swampy region at Legarto supplies the Terminal Company exclusively for railroad work and washing purposes.

The water works plant at Tejar was installed by Pearson and Company, Ltd., in 1904. The water flows by gravity from the Jamapa River into a receiving well, from which it is pumped into a small reservoir and from which it flows by gravity into a sedimentation basin having about four hours of rest. After passing through the sedimentation basin the settled water flows by gravity to four slow sand filter beds, the filtered water flows into a receiving well and then into a sump.

The water is pumped from the sump through a 15-inch and a 10-inch main into the distributing reservoir at Los Cocos. From this distributing reservoir, the water flows by gravity through a 20-inch main to Vera Cruz. The water plant has a capacity of 2,000,000 gallons per day, which is not sufficient for Vera Cruz.

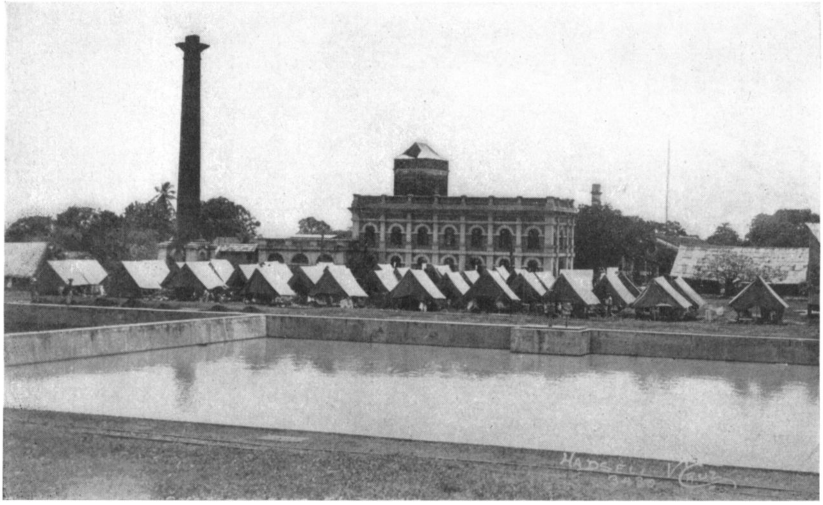

FIG. 3. ENCAMPMENT AT TEJAR, VERA CRUZ

In order to economize in the use of water, the supply is turned off from a part of the city for certain periods of the day and night, thus allowing the head to increase in the distributing reservoir at Los Cocos.

The inhabitants protect themselves during the time that the water is shut off by providing tanks on the roofs of their houses. These tanks are connected with the main supply by a float valve so that when the tank is full the city pressure is shut off.

An apparatus for putting chlorine in the filtered water was installed and ready to be used if the water became bad. But it was not necessary to use the chlorine in the water as very good results were obtained from the filters. Both chemical and bacteriological control analyses of the water were made in the Field Hospital Laboratory. The analysis of raw water showed gas in 1 cc., 0.5 cc., $\frac{1}{10}$ cc. samples in lactose broth and 4000 or 5000 bacteria per cubic centimeter on agar plates. The filtered water showed no gas in 1 cc., 0.5 cc., $\frac{1}{10}$ cc. samples in lactose broth and generally less than 50 bacteria per cubic centimeter on agar plates.

In order to increase the water supply, surveys were made and it was found that the present supply could be increased at least 45 per cent by installing a booster pump to raise the water into Los Cocos reservoir, thereby relieving the pressure on the line and allowing both pumps at Tejar to be used. This scheme was recommended and accepted, with the idea that the pump would be purchased as soon as the city had the money.

DISCUSSION

MR. J. M. GOODELL: It is only fair to the gentleman who has just been elected the first chairman of the Four States Section to say that the first water works built on any considerable scale in the Canal Zone by Americans were constructed under his direction. At the outset of our canal work conditions were very different from the well ordered efficiency of later days.

Mr. Davis had to find his construction plant in the jungle, where it had been left by the French. He had to train his Jamaica negroes, and those from Antigua, Martinique, Hayti and the other supply points for labor, to work in ways wholly unfamiliar and wholly abhorent to them. All this had to be done when disease was rampant, before the swamps were drained, the houses screened, the grass cut and the Zone made fit for a white man to live in.

The fight which Mr. Davis made there, against an enervating climate, insanitary surroundings, slack and unskilled labor, and the tangles of government red tape due to all details being then threaded through the main canal office in Washington, set a pace for achievement which formed one of the best stories of the Canal Zone. It was gratifying to learn from the author of this paper that General Gorgas considered the improved water supply at Panama so important in the conquest of the insanitary conditions there, and it is still more gratifying to be able to introduce to you the engineer who has all the credit for the achievement.